PRESSURE FILTERS

By Harold C. Stevens

The use of pressure filters is as old as the practice of rapid sand filtration; in fact, the first rapid sand or mechanical filter for treating a municipal supply, installed at Somerville, New Jersey, in 1885, was of the pressure type. At present, the aggregate capacity of pressure filters used for supplying potable water is not less than 265,000,000 gallons per day, which is about 13 per cent of the total capacity of all the rapid sand filters which have been installed on the North American continent. Plants range in size from very small capacities up to 21,000,000 gallons per day. The aggregate capacities of installations of various sizes are shown in the following table.

Combined capacities of pressure filter plants grouped according to size

SIZE OF PLANTS IN MILLIONS OF GALLONS DAILY CAPACITY	NUMBER OF PLANTS	COMBINED CAPACITY IN MILLIONS OF GALLONS PER DAY
over 20	1	21.0
10 to 20*	1	14.0
5 to 10*	9	69.0
2 to 5*	24	81.0
1 to 2*	21	33.0
0.5 to 1*	27	23.9
0.1 to 0.5	68	23.2
Totals	151	265.1

* Inclusive.

These figures do not include pressure filters used primarily for industrial service, nor those used for hotels, swimming pools, residences, etc.; there are hundreds of such installations. Some mills have filters of greater capacity than is ordinarily required for municipal service, and for the other classes individual filter capacities run as high as 1,000,000 gallons per day.

Despite their extensive use pressure filters have received but indifferent attention from sanitary engineers in general. This may per-

haps be accounted for by the lack of the structural features that always involve special design in the case of gravity filters. The unsightly appearance of the pressure filter as compared with the neatness of a gravity plant of concrete construction may also be a contributing factor. The fact that the filter bed is invisible has occasioned frequent and unduly severe criticism. The engineers of filter manufacturing companies have, however, through the years of slow development of rapid sand filtration, appreciated the value of the pressure filter as an efficient and economical device, and its practical development has been mainly due to their experience and efforts.

Extensive and careful studies of the gravity type of rapid sand filter have been made by many engineers, full records of operation have been pretty generally kept, and experience with them has been turned to good account. Much of the knowledge so gained is applicable to the pressure filter, since it is the same in principle as a positive head gravity filter. There is, however, little specific data with regard to pressure filters to aid in a close comparison with other types as to cost, efficiency and general merit.

This paucity of data is doubtless due to the small size of plants, to limited operating force, to the omission of automatic recorders and controlling devices in most cases, to technically unskilled supervision, and to the lack of incentive, which the activity of engineers could create, to systematic keeping of records. This condition is unfortunate, because there is no reason in the world why the pressure filter should not be made, by proper equipment, a thoroughly reliable and efficient means of purifying water, practically on a par with gravity filters and even superior to them under some conditions.

There are a few installations that are well equipped; a good many are operated with much care, and, so long as vigilance and intelligence are unfailingly exercised, are efficient and reliable; but most are, through lack of automatic controlling devices and through varying degrees of attention to operation, open to question as to their reliability in furnishing wholesome water at all times. Many small gravity filters are equally open to this same criticism.

Sterilization, as applied to water purification in recent years, has done much to palliate the uncertainties of filters of all types, slow sand as well as rapid sand. Nevertheless, constant efforts are still being made for the betterment of the gravity type, and why, then, should not the pressure type be equally improved? Certainly the

pressure filter cannot otherwise be brought to the high state of usefulness to which it is entitled.

The contention may be made that the pressure filter is essentially a comparatively small affair, not suitable for the treatment of large water supplies. This can hardly be admitted as sound reasoning, because in matters of public health, perfect safety is the object to be attained in all cases. Moreover, it is not true that pressure filters are unsuitable for large supplies. Atlanta, Georgia, has a plant of 21,000,000 gallons daily capacity. Filter units are most frequently of about half a million gallons daily capacity. They can readily be combined in groups, each operated by one set of devices, as many groups can be assembled in one plant as may be desired, and they can even be arranged in tiers if ground space is limited. The writer believes that pressure filters, fully equipped and carefully designed, are suitable for the largest water supplies, and that they will compare well with gravity filters as regards efficiency and cost of construction and of operation. Regarding cost, it is a significant fact that water supply companies, whose primary object is to make profits, usually adopt pressure filters in preference to gravity filters.

Standardization is one of the factors tending to keep down the cost of construction. It also favors rapid installation. The smaller sizes are actually kept in stock by filter companies, and for larger sizes designs are largely standard and many parts are stocked, so that it only requires a short time to effect the delivery of a filter of any ordinary size. The only deficiency is in the matter of refinements in controlling devices to a point of equality with gravity filters; and this will, of course, be remedied to keep pace with demand, if not in advance of it.

There does not seem to be any special difficulty in the way of applying refinements to the pressure filter, such as improved strainer systems and filter bottoms, loss of head indicators, rate and wash water controllers, and hydraulically operated gates. The question of chemical application has already been solved.

The pressure filter is essentially a positive head filter contained in a closed tank interposed in a pipe line, and provided with valves to permit reversal of flow for washing and the discharge of wash water and with a device for applying coagulant. In principle it does not differ from the positive head gravity filter, but it has a higher head of water over the sand, equal to the pressure in the pipe line, and it can be operated with a greater maximum loss of head.

The loss of head allowed is sometimes as high as 15 pounds, and is frequently 10 pounds. Probably no definite limit can be stated as generally applicable, as it undoubtedly varies with the character of the raw water, but in general it is either the point above which there begins to be danger of breaking the sediment layer through sudden changes in rate of filtration combined with excessive filtering pressure, or else it is the point above which further yield costs more on account of increased pumping pressure than is gained by lengthening the run.

Right here appears an objection to the very convenient practice of delivering water from the filter directly to the distribution system without any rate control. The filter must keep up with the demand and when an abnormally high draught occurs, as in case of fire, a very high filtering rate will result, and this sudden change, occurring at a time when the filter is about ready to wash, will be likely to cause the filter to break and deliver an impure effluent. Quite similarly it would seem that the sediment layer might be broken by pulsating pressure resulting from the action of reciprocating pumps.

Usually the only indication of the condition of the filter bed is the drop in pressure as shown by gauges on the effluent and influent mains and the appearance of the effluent. The pressure drop is a definite indication in the case of a single unit, but where the installation consists of more than one unit only the average loss of head is shown, and one unit may be badly clogged and delivering little water, while another is comparatively clean and operating at too high a rate. When rate controllers are used the loss of head gauges shows the condition of filters individually.

Pressure filters are made in two characteristic forms, horizontal and vertical, depending mainly upon the size of units, unless available space happens to be the controlling factor. Horizontal filter units, based on a filtering rate of two gallons per square foot per minute, are made for capacities ranging from 240,000 to 350,000 gallons per day; vertical filters are generally more suitable for lower capacities, ranging from 3000 to 230,000 gallons per day. Cost of construction is the principal determining feature as to form. In the horizontal filter, the sand surface is taken as the area of a plane through the axis and in the vertical filter it is the area of a plane perpendicular to the axis; so it is easy to see that for a given area of sand surface the vertical tank will be of larger diameter and will

require a disproportionate amount of metal both in the sides and heads and be correspondingly more expensive. It is not generally economical to build the vertical filters over 10 feet in diameter.

Coagulating and settling basins are in many instances not provided for pressure filters, the coagulant being injected into the influent main. All of the coagulum and sediment must therefore be deposited on the sand bed and more frequent washing would be necessary were it not for the pressure available to force the water through the filter.

Sometimes coagulating basins, consisting either of a separate closed cylinder, or of a compartment in the filter shell, are provided, but these are of small capacity as compared with the outside basins provided for gravity filters. Their value for purposes of sedimentation is only slight, but they are sometimes useful in providing a longer period, necessary with some waters, for thorough coagulation. In a number of instances coagulating and settling basins of ample size have been provided, or else existing reservoirs have been utilized as such. Settling basins are a practical necessity in treating muddy waters, but are generally omitted where comparatively clear water is to be filtered, unless a storage or distributing reservoir happens to be available. The ability of the pressure filter to handle unsettled water is one of its distinct advantages, especially where a low first cost is important.

Pressure filters have certain apparent advantages. They can be installed quickly; they are entirely above ground, and usually fit into some available space within a building; settling basins and clear well can frequently be eliminated; auxiliary pumping may often be avoided; less precision in operation is demanded, by present practice; the cost of installation is low, and the rate of filtration can be increased materially above the usually accepted rate of 2 gallons per square foot per minute. The last feature is especially important as it makes possible, without providing an excessively large nominal capacity, the practice of connecting the filter directly with the distribution system, the filter accommodating itself to the fluctuating demand without special attention.

Some of these advantages are not so real as they appear. The omission of a settling basin of ample capacity of course means a low installation cost, but the greater quantity of suspended matter which the filter alone must remove necessitates more frequent washing and correspondingly increases the percentage of filtered water

used for that purpose. The greater amount of wash water required tends in some measure to offset the saving otherwise effected by eliminating the settling basin. With very muddy water, unless the plant has an excessive filtering capacity, the clogging of the filter may be so rapid that it will be difficult to deliver a sufficient quantity of water and the loss of head may range very high, to the possible detriment of the effluent.

The elimination of low lift pumping, which the omission of a large settling basin may permit, is a definite saving in first cost, but does not materially affect the cost of operation, since the total lift of the water remains the same.

Less precise operation means an economic waste, sacrificed for the sake of convenience. It is very simple to wash a filter once a day whether it needs it or not, and provide for coagulation merely by filling the alum tank, as needed, letting the dosing device deliver a constant quantity of solution regardless of changes in the character of the raw water, but there can be no doubt that this practice results in the use of unnecessarily large amounts of wash water and alum.

The high rate of filtration that is attainable may or may not be a real advantage. So long as the effluent is not impaired, it is an advantage, but there is a limit somewhere. Above a certain point, further increase in loss of head will cost more on account of pumping pressure than it will save by the lengthening of runs and consequent reduction in wash water. There is also a critical point in the loss of head range at which the filter is likely to break, and also another point, varying with the character of the raw water, above which the filter will pass suspended matter without actually breaking. The rate of 2 gallons per square foot per minute, which has, until very recently, been credulously accepted as standard for all rapid sand filters, is really without foundation as a criterion for general practice. There are filters operating on colored, but practically clear water that cannot be made to produce a good effluent at such a high rate, and there are also filters treating turbid waters that can be operated at a much higher rate and still give perfectly good results. The success of pressure filters, with their widely varying rates and rule of thumb operation, gives evidence of the possibility of safely utilizing in many cases much higher rates than the normal rate heretofore accepted. While it is manifestly proper to take advantage of higher rates it should be done carefully and with due regard to limitations.

It must be admitted that pressure filters have shown surprisingly good results, in view of the opportunities that exist tending to inefficiency. This fact is of importance in indicating the possibilities open for improved filters.

The feature that deserves the most careful consideration is the utilization of higher rates of filtration within safe limits, making use of devices and appurtenances similar in purpose to those recognized as essential for gravity filters.

It is well known that negative head gravity filters have sometimes given trouble by passing hydrate unless operated at low rate. This substance is the neutral hydrate of aluminum, and harmless, but its presence in the effluent is considered objectionable on the sole ground of appearance. The actual quantity of hydrate of aluminum which thus passes a filter is exceedingly small, although its effect in giving the water a cloudy appearance may be marked.

This passage of hydrate appears to have been caused primarily by imperfect floc formation due to the peculiar properties of the raw water. Starting with this, the passage of hydrate through negative head filters appears to be aided by the suction effect on the underside of the sediment layer acting in conjunction with the scouring action of the water passing the filter, which detaches particles of hydrate and draws them deeper into the bed until they find lodgment at a point where the combined effect of these two forces is less. This action progresses downward as the material accumulates deeper and deeper in the bed, and as the suction head increases, until hydrate finally appears in the effluent. This phenomenon appears most frequently, if not only, with clear, colored waters, which form fragile, feathery flocs composed of very fine particles. In the treatment of turbid water the hydrate flocs are more substantial and are not drawn through the filter under the heads usually allowed in operation.

In the case of the treatment of clear waters it would appear on theoretical grounds that the passage of hydrate would not occur nearly as readily with a positive as with a negative head filter, for the reasons that the necessarily greater depth of water over the sand seemingly would tend to compact the sediment layer to an even greater degree than does induced suction from below in a negative head filter, and that there is no suction force tending to detach particles from the under side. Only the scouring effect of the water passing through the interstices of the sand remains and this, in the absence of the other

forces, may be increased, which means that a higher filtering rate may be permissible.

Here then, is a condition in which the positive head gravity filter which recovers much of the advantage it had lost to the negative head filter, although it still costs more to build and operate, because it may do effective work in cases where the negative head filter does not.

It is very likely that a general method will be devised to eliminate this apparent weakness of the negative head filter, which has been corrected in many individual cases, but the point to be made is this, the pressure filter is essentially a positive head filter, and possesses all its advantages, and moreover has a very large available working head which can be utilized to force water through a compact sediment layer and so secure reasonably large yields at the higher rate of filtration just indicated as being permissible with the positive head gravity filter.

Applying this reasoning farther, to the treatment of turbid water, it would seem that negative head filters might fail if a materially greater loss of head were applied than the customary 10 feet or so, and here again the pressure filter would have the same advantage that it has in the case of clear colored water.

One of the troubles frequently experienced with pressure filters is the necessity of adding sand to replace that lost in washing or of renewing all the sand occasionally, on account of accumulated mud within the bed. The loss of sand is plainly due to washing at too high a rate or to uneven washing. The accumulation of mud within the filter bed can only be due, if wash water is applied in the proper quantity, to imperfect distribution of wash water, just as is the case with gravity filters. Suitable wash water controlling devices and proper arrangement of the strainer system will obviate the trouble.

Only in a few instances is air used in the washing process. Surely if it is necessary for gravity filters it is equally important for pressure filters, since the conditions are exactly the same. Sometimes the interior of a pressure filter gets into a very foul smelling condition. Naturally the lack of ventilation would make odors particularly noticeable, but only an improperly washed filter would get into seriously bad condition in this respect. It would seem that the air wash should have a marked effect in preventing bad odors and that it may for this reason be especially desirable in connection with the pressure filter.

One kind of service for which the pressure filter is particularly well adapted is the treatment of water exclusively for industrial use, where the elimination of bacteria is not essential and where in some instances even complete clarification is not necessary. For this service the pressure filter in its usual form proves cheap and suitable. Good washing is of full importance, and a combined settling and coagulating basin may be a necessity in the case of a muddy water supply, but precise rate control and recording devices are not so important and direct service to the distribution system, allowing demand to control the rate of filtration, is often entirely satisfactory.

The cost of a thoroughly up-to-date installation of 1,000,000 gallons daily capacity would be about as follows:

Two 8-foot x 20-foot filters equipped in the ordinary way, including erection and foundations	$5,000
Controlling devices, air wash equipment and general improvements	1,300
Settling basin of two hours' capacity	3,500
Low-lift pumps	1,200
Superstructure	1,500
Total	$12,500

A first class gravity plant of the same capacity costs in the neighborhood of $20,000.

For large plants the cost of construction per million gallons daily capacity would be about $12,500 for gravity filters and about $9000 for pressure filters.

These figures are not offered as being exact and there will of course be considerable variation depending upon the character of the site and other conditions attending construction, and upon prices of labor and materials, but they will serve to indicate in a general way the relative cost of installation.

The cost of operation of pressure filters should be about the same as is the case with gravity filters, except that the cost of pumping may be a little greater, on account of the greater head utilized in the filter.

The cost of upkeep will be a little higher for pressure filters owing to the greater amount of steel work to be kept painted. Depreciation will also be a little more rapid, but the fact that certain pressure filters are still in use after twenty-five to thirty years of service shows this item to be almost insignificant.

The conclusions of the writer, summarized briefly, are as follows:

The pressure filter, as thus far constructed, is in some instances a very inferior means of purifying water, hygienically, and in other cases an excellent means, but on the average it is not entirely reliable.

There are no great obstacles in the way of developing it to the point of equality with the best gravity filters as regards efficiency and reliability, for any capacity and for most waters.

It is better adapted to the treatment of some waters than the gravity filter.

It is especially suited to very small water supplies and to the clarification of water for industrial uses.

The cost of construction of the highly developed pressure filter is materially less than that of the gravity filter, and low enough to more than offset a somewhat greater expense for operation and maintenance.

The improved pressure filter deserves the most careful consideration by sanitary engineers, filter manufacturers and public health officials.